# Design and Development of a 100 MVA HTS Generator

## Los Alamos National Laboratory


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CRADA with GE established August 15, 2002
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$430 k (GE in-kind)
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# Outline

- Results of FY 2003
  - Excitation System
  - Long Term Vacuum Maintenance
  - Heat Pipes
  - AC Losses
- FY 2003 Performance
- FY 2004 Plans
- Research Integration

# Generator Excitation System Results FY03

Excitation system provides dc current to rotor from ac source

**Design** - provided electrical design concept effective for rotors with large time constants

**Experiment** - proposed to demonstrate concept using 1430 MVA LANL generator which has open circuit field constant similar to superconducting rotor (large inductance, low resistance)

Task is completed

# Long Term Vacuum Maintenance - 1
# Motivation

HTS rotor winding at 20 - 40 K
surrounded by 300 K environment
vacuum represents main insulation

*Goal: no active pumping - getters to adsorb the quantity of the particular gas species evolved over about 5 years.*

# Long Term Vacuum Maintenance - 2
# Background

Unique outgassing and gettering properties determine vacuum life

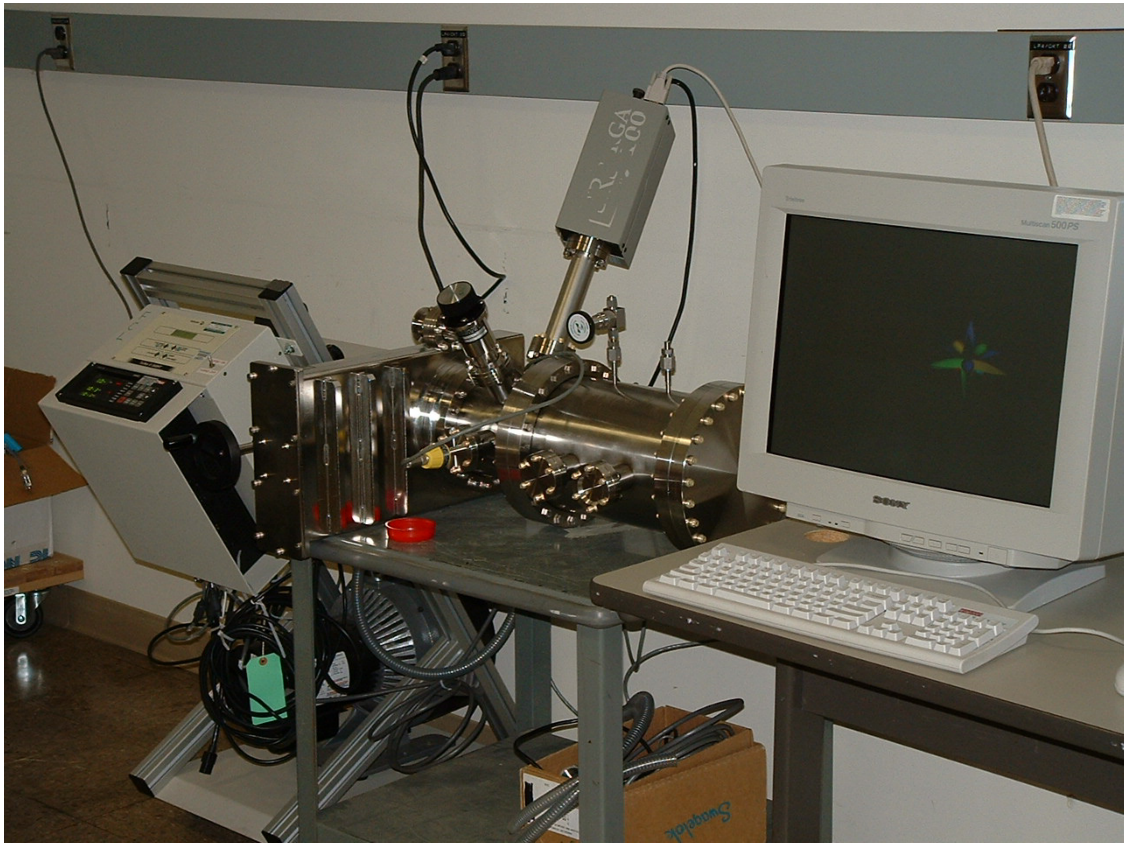
- Outgassing Properties depend on:
  - material (stainless steel, composites, aluminum, ...)
  - material preparation (machined, welded,…)
  - cleaning (materials/chemicals, methods)
  - handling
  - assembly environment
  - operating temperature
- Gettering Ability depends on:
  - getter material
  - quantity of getter
  - gas species
  - quantity of gases present
  - temperature of getter

# Long Term Vacuum Maintenance - 3
# Results FY03

## Outgassing Measurements

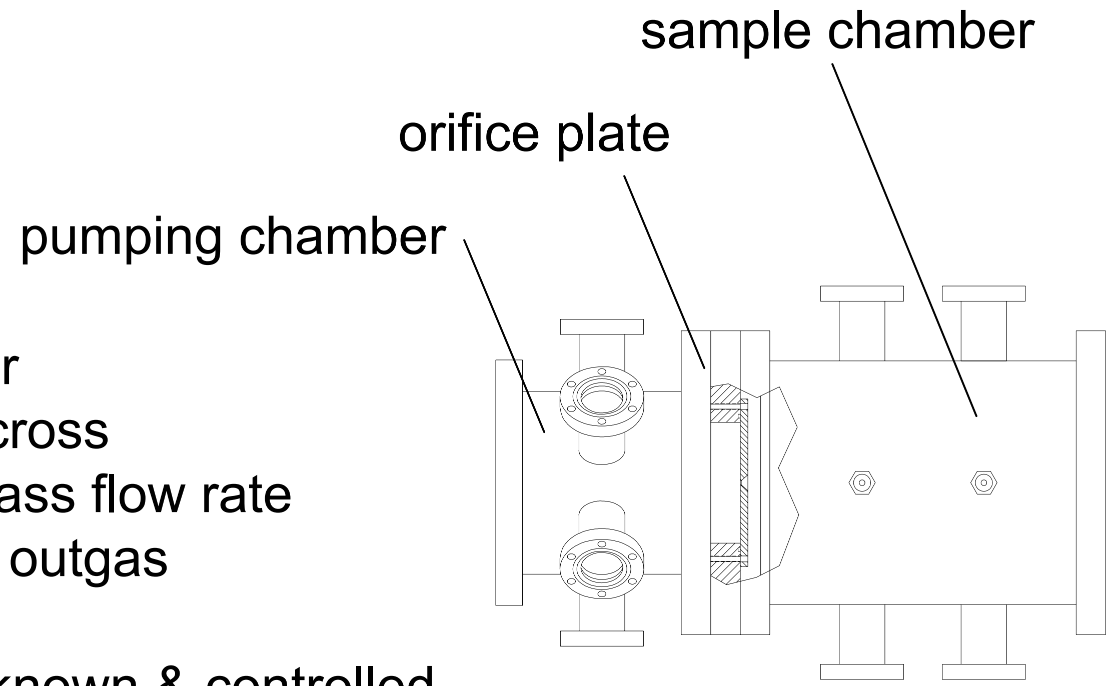
Design/fab/assemble vacuum chambers
- sample
- pump

pressure gauges
residual gas analyzer
data acquisition sys.



# Long Term Vacuum Maintenance - 4 Approach

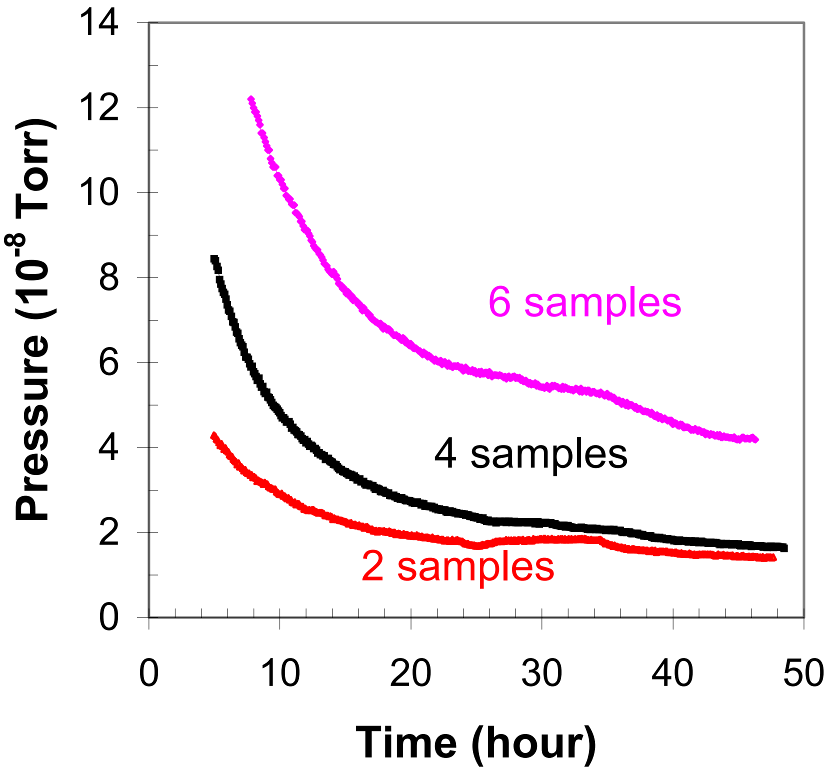
## Outgassing

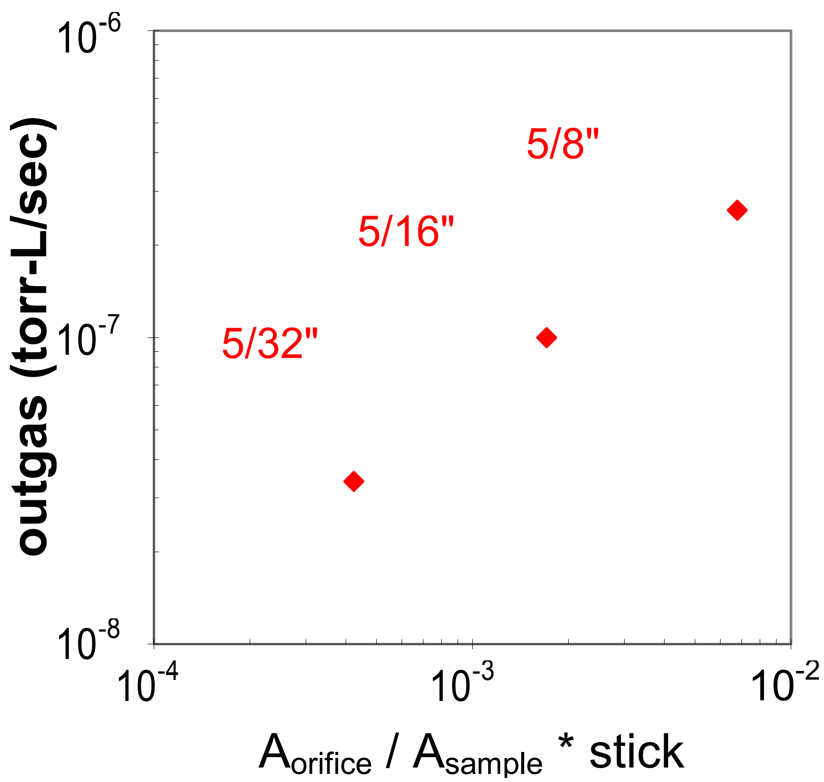



- Residual Gas Analyzer
- Pressure difference across known orifice yields mass flow rate
- Sample chamber must outgas less than sample
- Temperature must be known & controlled
- Accommodate easy sample change-out (many samples measured)
- Must account for re-adsorption:

$$\text{outgas}_{\text{actual}} / \text{outgas}_{\text{measured}} \sim 10^3$$

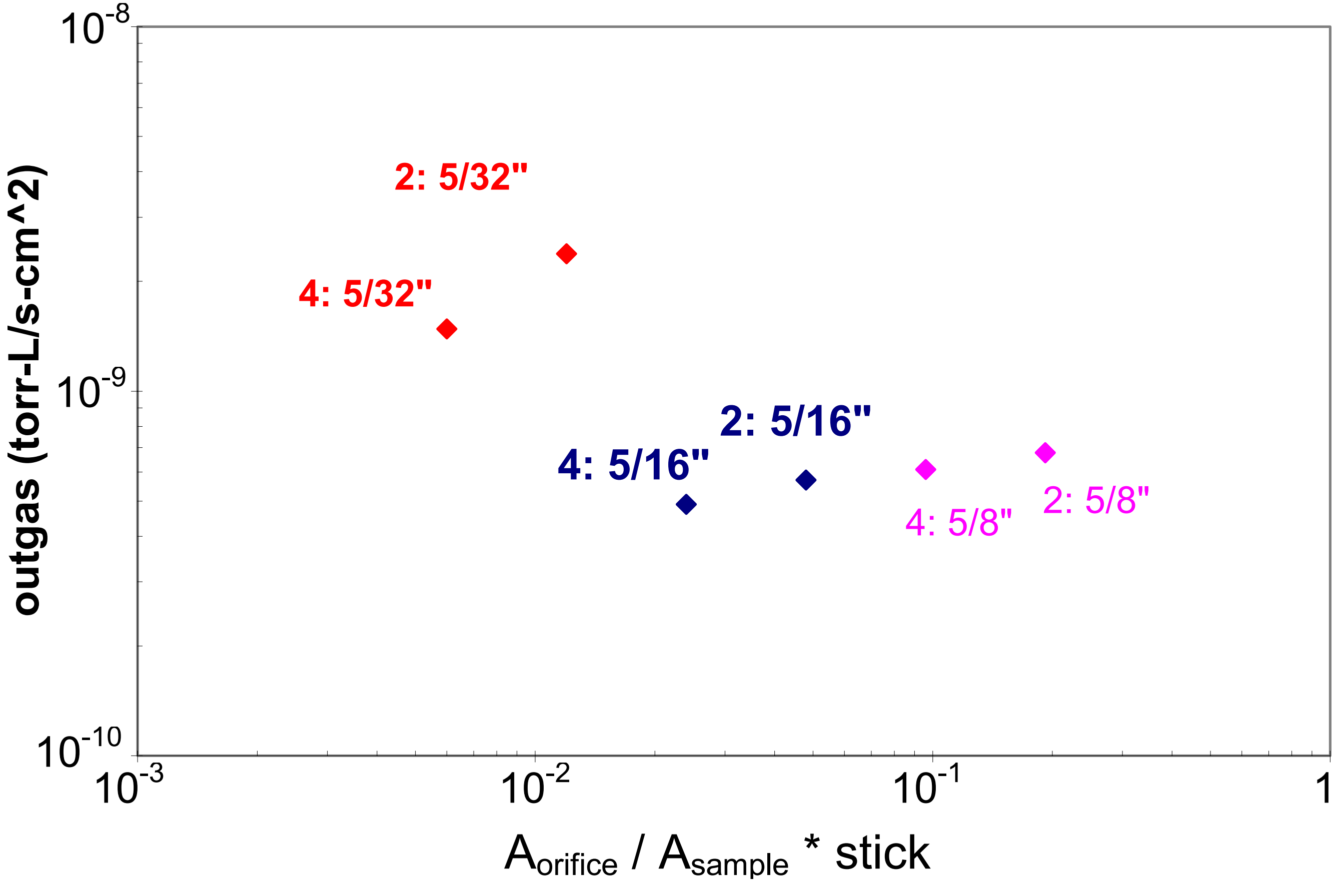
# Long Term Vacuum Maintenance - 5
# Results FY03



# Long Term Vacuum Maintenance - 6
# Results FY03

Data for *one* material

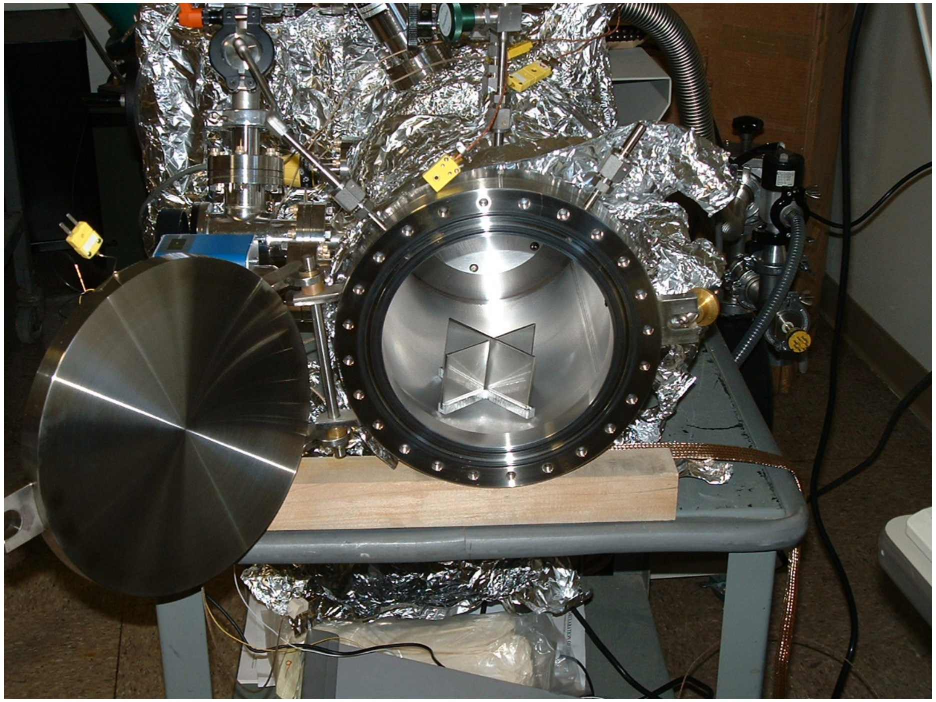


# *Long Term Vacuum Maintenance - 7 Results FY03*

## Gettering Measurements

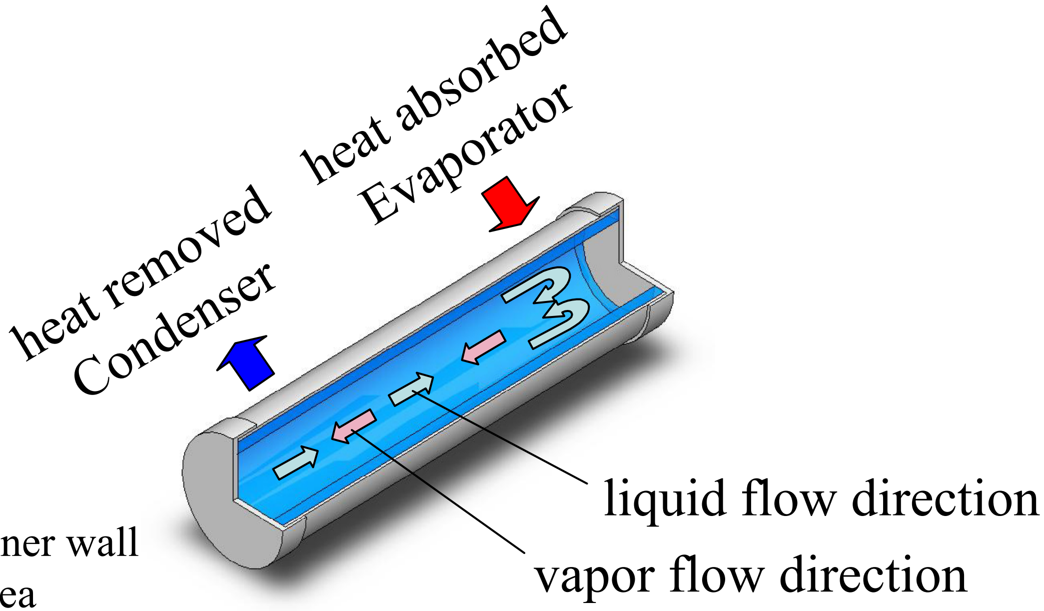
Vacuum system modification designed

Cryocooler to be added to door



# Heat Pipes - 1
# Motivation

- Need an efficient method to cool and remove heat from HTS rotor and transfer the heat to cryocooler.
- Effective thermal conductivity orders of magnitude greater than copper. => $\Delta T$ required to transfer amount of heat can be small
- Severe operating conditions on rotor and heat pipe.




Liquid flows along tube inner wall
Vapor returns in central area

# Heat Pipes - 2
# Results FY03

- Grover (LANL) invented modern day heat pipe 1963
- Existing & validated (20 yrs) heat pipe model extended
  - included rotational aspects
  - evaluated performance capability
  - identified performance issues and limits
  - designed model validating experiments
    - based on similarity of performance via dimensional analysis
- Room temperature experiment to validate is progressing
  - apparatus and data acquisition equipment designed, costed, being procured

# AC Losses
# Motivation & Results FY03

- Conductor AC losses impact:
  - steady state heat loads
  - transient fault condition response
    - coil stability
    - conductor ‘protection’
  - excitation system choice
- AC loss model developed for comparison to GE data
- Results used to
  - predict heat generation in HTS rotor
  - assess losses associated with excitation system choice

# FY 2003 Performance

- CRADA established August 2002
- All FY03 deliverables met:
  - ✔ ***Excitation system*** - documents proposing system design and test delivered to GE, task complete
  - ✔ ***Outgassing properties of materials*** - vacuum system design, fab'd, sample materials sent by GE being measured, data interpreted/discussed in telecons, paper to be presented at CEC
  - ✔ ***Getter system design*** - cryocooler incorporated in design, system modifications in progress, GE data and design received
  - ✔ ***Heat pipe assessment*** - model developed, three reports sent to GE, validating apparatus designed, being procured, GE performed supporting analysis
  - ✔ ***Engineering support - AC losses*** - model developed, test support provided by LANL, validating experiments being considered

# FY 2004 Plans

- Specific CRADA deliverables (final reports) will be met:
  - ***Outgassing material*** characterization of all GE materials
  - ***Getter material*** evaluation based on residual gasses
  - Long term ***vacuum maintenance*** prescription based on outgassing and getter data and GE design
  - ***Rotating heat pipe*** assessment - experiment built, data will be acquired, compared to modeling, incorporation into rotor will be analyzed
  - ***AC loss*** evaluation - measurement sensors will be delivered to GE, and coil measurements will be performed on GE coil
  - ***2nd generation HTS*** conductor impact on GE rotor will be assessed

# Research Integration

- Close interactions with GE, review direction, efforts, and results
- Exchange of samples, sensors, software models with GE
- Interactions with LANL experts; materials, data acquisition
- Paper on outgassing to be presented at CEC, published in Advances in Cryogenic Engineering
- Interactions with Prof. Campuzano of University of Illinois-Chicago on outgassing
- Interactions with Prof. Razani of University of New Mexico on heat pipes (PhD thesis advisor of Todd Jankowski)

# Summary

- CRADA established with GE Aug 2002
- Significant support being provided to GE in high technical risk areas
- Milestones and deliverables are being met
- Challenging tasks and schedule for next year have been established